

conservation scientists. It is also related to agricultural production occupations such as farmer and farm manager and cooperative extension service agent. Certain specialties of agricultural science are also related to other occupations. For example, the work of animal scientists is related to that of veterinarians; horticulturists, to landscape architects; and soil scientists, to soil conservationists.

Sources of Additional Information

Information on careers in agricultural science is available from:

- ☛ American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711-1086.
- ☛ Food and Agricultural Careers for Tomorrow, Purdue University, 1140 Agricultural Administration Bldg., West Lafayette, IN 47907-1140.

For information on careers in food technology, write to:

- ☛ Institute of Food Technologists, Suite 300, 221 N. LaSalle St., Chicago IL 60601-1291.

For information on education in food safety, contact:

- ☛ National Alliance for Food Safety, Office of the Secretariat, 205 Agriculture Building, University of Arkansas, Fayetteville, AR 72701.

For information on careers in entomology, contact:

- ☛ Entomological Society of America, 9301 Annapolis Rd., Lanham, MD 20706, Attn: Public Relations Coordinator.

Information on acquiring a job as an agricultural scientist with the Federal Government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number, or call (912) 757-3000 (TDD 912-744-2299). That number is not toll-free and charges may result. Information also is available from their Internet site: <http://www.usajobs.opm.gov>

Biological and Medical Scientists

(O*NET 24308A, 24308B, 24308C, 24308D, 24308E, 24308F, 24308G, 24308H, 24308J, and 24311)

Significant Points

- Biological scientists usually require a Ph.D. degree for independent research but a master's degree is sufficient for some jobs in applied research or product development; a bachelor's degree is adequate for some non-research jobs.
- Medical scientist jobs require a Ph.D. degree in a biological science, but some jobs need a medical degree.
- Doctoral degree holders face considerable competition for independent research positions; holders of bachelor's or master's degrees in biological science can expect better opportunities in non-research positions.

Nature of the Work

Biological and medical scientists study living organisms and their relationship to their environment. Most specialize in some area of biology such as zoology (the study of animals) or microbiology (the study of microscopic organisms).

Many biological scientists and virtually all medical scientists work in research and development. Some conduct basic research to advance knowledge of living organisms, including viruses, bacteria, and other infectious agents. Past research has resulted in the development of vaccines, medicines, and treatments for cancer and other diseases. Basic biological and medical research continues to provide the building blocks necessary to develop solutions to human health problems and to preserve and repair the natural environment. Many biological and medical scientists work independently in private industry, university, or government laboratories, often

exploring new areas of research or expanding on specialized research started in graduate school. Those who are not wage and salary workers in private industry typically submit grant proposals to obtain funding for their projects. Colleges and universities, private industry, and Federal Government agencies, such as the National Institutes of Health and the National Science Foundation, contribute to the support of scientists whose research proposals are determined to be financially feasible and have the potential to advance new ideas or processes.

Biological and medical scientists who work in applied research or product development use knowledge provided by basic research to develop new drugs and medical treatments, increase crop yields, and protect and clean up the environment. They usually have less autonomy than basic researchers to choose the emphasis of their research, relying instead on market-driven directions based on the firm's products and goals. Biological and medical scientists doing applied research and product development in private industry may be required to express their research plans or results to nonscientists who are in a position to veto or approve their ideas, and they must understand the business impact of their work. Scientists are increasingly working as part of teams, interacting with engineers, scientists of other disciplines, business managers, and technicians. Some biological and medical scientists also work with customers or suppliers, and manage budgets.

Biological and medical scientists who conduct research usually work in laboratories and use electron microscopes, computers, thermal cyclers, or a wide variety of other equipment. Some conduct experiments using laboratory animals or greenhouse plants. For some biological scientists, a good deal of research is performed outside of laboratories. For example, a botanist may do research in tropical rain forests to see what plants grow there, or an ecologist may study how a forest area recovers after a fire.

Some biological and medical scientists work in managerial or administrative positions, usually after spending some time doing research and learning about the firm, agency, or project. They may plan and administer programs for testing foods and drugs, for example, or direct activities at zoos or botanical gardens. Some biological scientists work as consultants to business firms or to government, while others test and inspect foods, drugs, and other products.

In the 1980s, swift advances in basic biological knowledge related to genetics and molecules spurred growth in the field of biotechnology. Biological and medical scientists using this technology manipulate the genetic material of animals or plants, attempting to make organisms more productive or resistant to disease. Research using biotechnology techniques, such as recombining DNA, has led to the discovery of important drugs, including human insulin and growth hormone. Many other substances not previously available in large quantities are starting to be produced by biotechnological means; some may be useful in treating cancer and other diseases. Today, many biological and medical scientists are involved in biotechnology, including those who work on the Human Genome project, isolating, identifying, and sequencing human genes. This work continues to lead to the discovery of the genes associated with specific diseases and inherited traits, such as certain types of cancer or obesity. These advances in biotechnology have opened up research opportunities in almost all areas of biology, including commercial applications in agriculture, environmental remediation, and the food and chemical industries.

Most biological scientists who come under the category of *biologist* are further classified by the type of organism they study or by the specific activity they perform, although recent advances in the understanding of basic life processes at the molecular and cellular levels have blurred some traditional classifications.

Aquatic biologists study plants and animals living in water. *Marine biologists* study salt water organisms and *limnologists* study fresh water organisms. Marine biologists are sometimes mistakenly called oceanographers, but oceanography is the study of the

physical characteristics of oceans and the ocean floor. (See the statement on geologists, geophysicists, and oceanographers elsewhere in the *Handbook*.)

Biochemists study the chemical composition of living things. They analyze the complex chemical combinations and reactions involved in metabolism, reproduction, growth, and heredity. Biochemists and molecular biologists do most of their work in biotechnology, which involves understanding the complex chemistry of life.

Botanists study plants and their environment. Some study all aspects of plant life; others specialize in areas such as identification and classification of plants, the structure and function of plant parts, the biochemistry of plant processes, the causes and cures of plant diseases, and the geological record of plants.

Microbiologists investigate the growth and characteristics of microscopic organisms such as bacteria, algae, or fungi. **Medical microbiologists** study the relationship between organisms and disease or the effect of antibiotics on microorganisms. Other microbiologists specialize in environmental, food, agricultural, or industrial microbiology, virology (the study of viruses), or immunology (the study of mechanisms that fight infections). Many microbiologists use biotechnology to advance knowledge of cell reproduction and human disease.

Physiologists study life functions of plants and animals, both in the whole organism and at the cellular or molecular level, under normal and abnormal conditions. Physiologists often specialize in functions such as growth, reproduction, photosynthesis, respiration, or movement, or in the physiology of a certain area or system of the organism.

Zoologists study animals—their origin, behavior, diseases, and life processes. Some experiment with live animals in controlled or natural surroundings while others dissect dead animals to study their structure. Zoologists are usually identified by the animal group studied—ornithologists (birds), mammalogists (mammals), herpetologists (reptiles), and ichthyologists (fish).

Ecologists study the relationship among organisms and between organisms and their environments and the effects of influences such as population size, pollutants, rainfall, temperature, and altitude.

Agricultural and food scientists, who are sometimes referred to as biological scientists, are included in a separate statement elsewhere in the *Handbook*.

Biological scientists who do biomedical research are usually called **medical scientists**. Medical scientists work on basic research into normal biological systems to understand the causes of and to discover treatment for disease and other health problems. Medical scientists try to identify changes in a cell, chromosome, or even gene that signal the development of medical problems, such as different types of cancer. After identifying structures of or changes in

organisms that provide clues to health problems, medical scientists work on the treatment of problems. For example, a medical scientist involved in cancer research may formulate a combination of drugs that will lessen the effects of the disease. Medical scientists with a medical degree can administer these drugs to patients in clinical trials, monitor their reactions, and observe the results. (Medical scientists without a medical degree normally collaborate with a medical doctor who deals directly with patients.) The medical scientist will return to the laboratory to examine the results and, if necessary, adjust the dosage levels to reduce negative side effects or to try to induce even better results. In addition to using basic research to develop treatments for health problems, medical scientists attempt to discover ways to prevent health problems from developing, such as affirming the link between smoking and increased risk of lung cancer, or between alcoholism and liver disease.

Working Conditions

Biological and medical scientists usually work regular hours in offices or laboratories and usually are not exposed to unsafe or unhealthy conditions. Those who work with dangerous organisms or toxic substances in the laboratory must follow strict safety procedures to avoid contamination. Medical scientists also spend time working in clinics and hospitals administering drugs and treatments to patients in clinical trials. Many biological scientists such as botanists, ecologists, and zoologists take field trips that involve strenuous physical activity and primitive living conditions.

Some biological and medical scientists depend on grant money to support their research. They may be under pressure to meet deadlines and conform to rigid grant-writing specifications when preparing proposals to seek new or extended funding.

Employment

Biological and medical scientists held about 112,000 jobs in 1998. Almost 4 in 10 biological scientists were employed by Federal, State, and local governments. Federal biological scientists worked mainly in the U.S. Departments of Agriculture, the Interior, and Defense, and in the National Institutes of Health. Most of the rest worked in the drug industry, which includes pharmaceutical and biotechnology establishments; hospitals; or research and testing laboratories. About 2 in 10 medical scientists worked in State government, with most of the remainder found in research and testing laboratories, educational institutions, the drug industry, and hospitals.

In addition, many biological and medical scientists held biology faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook*.)

Training, Other Qualifications, and Advancement

For biological scientists, the Ph.D. degree usually is necessary for independent research and for advancement to administrative positions. A master's degree is sufficient for some jobs in applied research or product development and for jobs in management, inspection, sales, and service. The bachelor's degree is adequate for some non-research jobs. Some graduates with a bachelor's degree start as biological scientists in testing and inspection, or get jobs related to biological science such as technical sales or service representatives. In some cases, graduates with a bachelor's degree are able to work in a laboratory environment on their own projects, but this is unusual. Some may work as research assistants. Others become biological technicians, medical laboratory technologists or, with courses in education, high school biology teachers. (See the statements on clinical laboratory technologists and technicians; science technicians; and kindergarten, elementary, and secondary school teachers elsewhere in the *Handbook*.) Many with a bachelor's degree in biology enter medical, dental, veterinary, or other health profession schools.

Most colleges and universities offer bachelor's degrees in biological science and many offer advanced degrees. Curriculums for advanced degrees often emphasize a subfield such as microbiology



Biological and medical scientists who conduct research usually work in laboratories and use microscopes, computers, and other equipment.

or botany, but not all universities offer all curriculums. Advanced degree programs include classroom and field work, laboratory research, and a thesis or dissertation. Biological scientists who have advanced degrees often take temporary postdoctoral research positions that provide specialized research experience. In private industry, some may become managers or administrators within biology; others leave biology for nontechnical managerial, administrative, or sales jobs.

Biological scientists should be able to work independently or as part of a team and be able to communicate clearly and concisely, both orally and in writing. Those in private industry, especially those who aspire to management or administrative positions, should possess strong business and communication skills and be familiar with regulatory issues and marketing and management techniques. Those doing field research in remote areas must have physical stamina.

The Ph.D. degree in a biological science is the minimum education required for prospective medical scientists because the work of medical scientists is almost entirely research oriented. A Ph.D. degree qualifies one to do research on basic life processes or on particular medical problems or diseases, and to analyze and interpret the results of experiments on patients. Medical scientists who administer drug or gene therapy to human patients, or who otherwise interact medically with patients—such as drawing blood, excising tissue, or performing other invasive procedures—must have a medical degree. It is particularly helpful for medical scientists to earn both Ph.D. and medical degrees.

In addition to formal education, medical scientists usually spend several years in a postdoctoral position before they apply for permanent jobs. Postdoctoral work provides valuable laboratory experience, including experience in specific processes and techniques, such as gene splicing, which are transferable to other research projects. In some institutions, the postdoctoral position can lead to a permanent position.

Job Outlook

Despite prospects of faster-than-average job growth over the 1998-2008 period, biological and medical scientists can expect to face considerable competition for basic research positions. The Federal Government funds much basic research and development, including many areas of medical research. Recent budget tightening has led to smaller increases in Federal basic research and development expenditures, further limiting the dollar amount of each grant and slowing the growth of the number of grants awarded to researchers. At the same time, the number of newly trained scientists has continued to increase at a steady rate, so both new and established scientists have experienced greater difficulty winning and renewing research grants. If the number of advanced degrees awarded continues to grow unabated, this competitive scenario is likely to persist. Additionally, applied research positions in private industry may become more difficult to obtain if more scientists seek jobs in private industry than in the past due to the competitive job market for college and university faculty.

Opportunities for those with a bachelor's or master's degree in biological science are expected to be better. The number of science-related jobs in sales, marketing, and research management, for which non-Ph.D.'s usually qualify, are expected to be more plentiful than independent research positions. Non-Ph.D.'s may also fill positions as science or engineering technicians or health technologists and technicians. Some become high school biology teachers, while those with a doctorate in biological science may become college and university faculty. (See statements on science technicians, engineering technicians, health technologists and technicians, secondary school teachers, and college and university faculty elsewhere in the *Handbook*.)

Biological and medical scientists enjoyed very rapid gains in employment between the mid-1980s and mid-1990s, in part reflecting increased staffing requirements in new biotechnology companies.

Employment growth should slow somewhat as increases in the number of new biotechnology firms slows and existing firms merge or are absorbed into larger ones. However, much of the basic biological research done in recent years has resulted in new knowledge, including the isolation and identification of new genes. Biological and medical scientists will be needed to take this knowledge to the next stage, which is the understanding of how certain genes function within an entire organism so that gene therapies can be developed to treat diseases. Even pharmaceutical and other firms not solely engaged in biotechnology are expected to increasingly use biotechnology techniques, spurring employment increases for biological and medical scientists. In addition, efforts to discover new and improved ways to clean up and preserve the environment will continue to add to growth. More biological scientists will be needed to determine the environmental impact of industry and government actions and to prevent or correct environmental problems. Expected expansion in research related to health issues, such as AIDS, cancer, and Alzheimer's disease, should also result in employment growth.

Biological and medical scientists are less likely to lose their jobs during recessions than those in many other occupations because many are employed on long-term research projects. However, a recession could further influence the amount of money allocated to new research and development efforts, particularly in areas of risky or innovative research. A recession could also limit the possibility of extension or renewal of existing projects.

Earnings

Median annual earnings of biological scientists were \$46,140 in 1998. The middle 50 percent earned between \$35,200 and \$67,850. The lowest 10 percent earned less than \$27,930 and the highest 10 percent earned more than \$86,020. Median annual earnings in the industries employing the largest numbers of biological scientists in 1997 were:

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| Federal Government | \$48,600 |
| Drugs | 46,300 |
| Research and testing services | 40,800 |
| State Government, except education and hospitals | 38,000 |

Median annual earnings of medical scientists were \$50,410 in 1998. The middle 50 percent earned between \$37,740 and \$79,370. The lowest 10 percent earned less than \$29,550 and the highest 10 percent earned more than \$109,050. Median annual earnings of medical scientists in 1997 were \$52,200 in research and testing services.

According to the National Association of Colleges and Employers, beginning salary offers in 1999 averaged \$29,000 a year for bachelor's degree recipients in biological science; about \$34,450 for master's degree recipients; and about \$45,700 for doctoral degree recipients.

In the Federal Government in 1999, general biological scientists in nonsupervisory, supervisory, and managerial positions earned an average salary of \$56,000; microbiologists, \$62,600; ecologists, \$57,100; physiologists, \$71,300; and geneticists, \$68,200.

Related Occupations

Many other occupations deal with living organisms and require a level of training similar to that of biological and medical scientists. These include agricultural scientists, such as animal breeders, horticulturists, and entomologists, and the conservation occupations of forester, range manager, and soil conservationist. Many health occupations, such as medical doctors, dentists, and veterinarians, are also related to those in the biological sciences.

Sources of Additional Information

For information on careers in the biological sciences, contact:
 American Institute of Biological Sciences, Suite 200, 1444 I St. NW., Washington, DC 20005. Internet: <http://www.aibs.org>

For information on careers in physiology, contact:

☛ American Physiological Society, Education Office, 9650 Rockville Pike, Bethesda, MD 20814. Internet: <http://www.faseb.org/aps>

For information on careers in biotechnology, contact:

☛ Biotechnology Industry Organization, 1625 K St. NW., Suite 1100, Washington, DC 20006. Internet: <http://www.bio.org>

For information on careers in biochemistry, contact:

☛ American Society for Biochemistry and Molecular Biology, 9650 Rockville Pike, Bethesda, MD 20814.

Internet: <http://www.faseb.org/asbmb>

For a brochure titled, *Is a Career in the Pharmaceutical Sciences Right for Me?*, contact:

☛ American Association of Pharmaceutical Scientists, 1650 King Street, Suite 200, Alexandria, VA 22314.

Internet: <http://www.aaps.org/sciaffairs/careerinps.htm>

For information on careers in botany, contact:

☛ Botanical Society of America, Business Office, 1735 Neil Ave., Columbus, OH 43210-1293. Internet: <http://www.botany.org>

For information on careers in microbiology, contact:

☛ American Society for Microbiology, Office of Education and Training—Career Information, 1325 Massachusetts Ave. NW., Washington, DC 20005. Internet: <http://www.asmsa.org>

For a free copy of “Sources of Career Information on Careers in Biology, Conservation, and Oceanography,” visit the Smithsonian Institute website at <http://www.si.edu/resource/faq/nmnh/careers.htm> or call (202) 782-4612. That number is not toll-free and charges may result.

Information on acquiring a job as a biological or medical scientist with the Federal government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; TDD (912) 744-2299. That number is not toll-free and charges may result. Information also is available from their Internet site: <http://www.usajobs.opm.gov>

Conservation Scientists and Foresters

(O*NET 24302A, 24302B, 24302C, 24302D, and 24302E)

Significant Points

- About 2 out of 3 work for Federal, State, or local governments.
- A bachelor's degree in forestry, range management, or a related field is usually the minimum educational requirement.
- Projected average employment growth will stem from continuing emphasis on environmental protection and responsible land management.

Nature of the Work

Forests and rangelands supply wood products, livestock forage, minerals, and water; serve as sites for recreational activities; and provide habitats for wildlife. Conservation scientists and foresters manage, develop, use, and help protect these and other natural resources.

Foresters manage forested lands for a variety of purposes. Those working in private industry may procure timber from private landowners. To do this, foresters contact local forest owners and gain permission to take inventory of the type, amount, and location of all standing timber on the property, a process known as timber cruising. Foresters then appraise the timber's worth, negotiate the purchase of timber, and draw up a contract for procurement. Next, they subcontract with loggers or pulpwood cutters for tree removal, aid in road layout, and maintain close contact with the subcontractor's workers and the landowner to ensure that the work meets the landowner's requirements, as well as Federal, State, and

local environmental specifications. Forestry consultants often act as agents for the forest owner, performing these duties and negotiating timber sales with industrial procurement foresters.

Throughout the process, foresters consider the economics of the purchase as well as the environmental impact on natural resources. To do this, they determine how best to conserve wildlife habitats, creek beds, water quality, and soil stability and how best to comply with environmental regulations. Foresters must balance the desire to conserve forested ecosystems for future generations with the need to use forest resources for recreational or economic purposes.

Through a process called regeneration, foresters also supervise the planting and growing of new trees. They choose and prepare the site, using controlled burning, bulldozers, or herbicides to clear weeds, brush, and logging debris. They advise on the type, number, and placement of trees to be planted. Foresters then monitor the seedlings to ensure healthy growth and to determine the best time for harvesting. If they detect signs of disease or harmful insects, they decide on the best course of treatment to prevent contamination or infestation of healthy trees.

Foresters who work for State and Federal governments manage public forests and parks and also work with private landowners to protect and manage forest land outside of the public domain. They may also design campgrounds and recreation areas.

Foresters use a number of tools to perform their jobs. Clinometers measure the heights, diameter tapes measure the diameter, and increment borers and bark gauges measure the growth of trees so that timber volumes can be computed and future growth estimated. Photogrammetry and remote sensing (aerial photographs and other imagery taken from airplanes and satellites) often are used for mapping large forest areas and for detecting widespread trends of forest and land use. Computers are used extensively, both in the office and in the field, for the storage, retrieval, and analysis of information required to manage the forest land and its resources.

Range managers, also called *range conservationists*, *range ecologists*, or *range scientists*, manage, improve, and protect rangelands to maximize their use without damaging the environment. Rangelands cover about 1 billion acres of the United States, mostly in the western States and Alaska. They contain many natural resources, including grass and shrubs for animal grazing, wildlife habitats, water from vast watersheds, recreation facilities, and valuable mineral and energy resources. Range managers help ranchers attain optimum livestock production by determining the number and kind of animals to graze, the grazing system to use, and the best season for grazing. At the same time, however, they maintain soil stability and vegetation for other uses such as wildlife habitats and outdoor recreation. They also plan and implement revegetation of disturbed sites.



Conservation scientists and foresters often use aerial photographs to map large forest areas.